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NACA

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FREE-FLIGHT TESTS OF THREE 1/9-SCALE MODELS OF THE WING—RAM-JET CONFIGURATION OF THE GRUMMAN XSSM-N-6a (RIGEL) MISSILE TO INVESTIGATE THE POSSIBILITY OF FLUTTER

TED NO. NACA DE 223

By Burke R. O'Kelly and William T. Lauten, Jr.

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Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

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FREE-FLIGHT TESTS OF THREE 1/9-SCALE MODELS OF THE WING—RAM-JET CONFIGURATION OF THE GRUMMAN XSSM-N-6a (RIGEL) MISSILE TO INVESTIGATE THE POSSIBILITY OF FLUTTER

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SUMMARY

Cold-flow free-flight tests at zero lift have been made to investigate the possibility of flutter of simulated wing—ram-jet-nacelle configurations which were 1/9-scale models of the wing and ram-jet nacelles of the Grumman XSSM-N-6a (Rigel) missile. Tests were performed on three different configurations, the differences being in the length of the ram-jet nacelle in relation to the wing chord, in the mass moment of inertia and mass of the ram-jet nacelles, and in the vertical-stabilizer configuration of the nacelles. In the first two tests the maximum Mach number obtained was approximately 2.0 and in the third the maximum Mach number was 1.35.

The mass, mass moment of inertia, center of gravity, and exterior geometry of the nacelle were scaled dynamically and the supporting wing was scaled in plan form but was made less stiff than the scaled stiffness of the prototype. Since no flutter was obtained in any of the three flights it is thought that the prototype should also be free from flutter up to the top Mach number of the model tests.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, cold-flow free-flight tests at zero lift at transonic and supersonic

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speeds have been conducted jointly by the Dynamic Loads Division and Pilotless Aircraft Research Division of the Langley Laboratory to determine the possibility of flutter of the wing—ram-jet-nacelle configuration proposed for the Grumman XSSM-N-6a (Rigel) missile. This missile is designed to be boosted to transonic speed where ram-jet engines, which are mounted at the tips of short unswept wings, take over and carry the missile up to a top Mach number of approximately 2.0.

Since there is little, if any, experimental or theoretical information available on configurations of this type it was decided that these free-flight tests of scaled models would give the best indication of the flutter susceptibility of the prototype. The simulated ram-jet engines were 1/9-scale dynamic models of the prototype. The supporting wing was 1/9-scale in plan form but the stiffness was adjusted to give a lower bending and torsional frequency and the same frequency ratio. The models were purposely built a little weaker than the scaled values of the prototype in order to provide some margin of safety; that is, if the weakened models did not flutter one might expect the prototype to have an adequate margin of safety against flutter.

SYMBOLS

A_1 station at which cowl area is measured

A_2 station at which minimum area is measured

a elastic axis of wing section, $\frac{2 \times \text{percent chord}}{100} - 1$

$a + x_\alpha$ center of gravity of wing section, $\frac{2 \times \text{percent chord}}{100} - 1$

d distance from entrance lip of ram-jet to wing elastic axis, in.

EI average wing bending stiffness, lb-in.^{2}

f_α natural wing torsional frequency, cps

f_h natural wing bending frequency, cps

I_{cg} mass-moment of inertia of ram-jet in pitch about its center of gravity, in.-lb-sec^2

JG average wing torsional stiffness, lb-in.^{2}

M Mach number

m mass of ram-jet, $\frac{\text{lb-sec}^2}{\text{in.}}$

ρ atmospheric density, slugs/cu ft

t time after firing, sec

V free-stream velocity, fps

x distance along chord from leading edge, in.

y one-half thickness, in.

Z distance from wing elastic axis to ram-jet center of gravity measured positively aft of elastic axis, in.

Subscripts:

max value at maximum velocity of flight test

MODELS AND INSTRUMENTATION

Models

The models consisted of a 5-inch cordite rocket motor which served as the major portion of the fuselage, a nose section which was attached to the forward end of the rocket motor, a wing attachment assembly and the wing—ram-jet-nacelle combination. A sketch of the general model arrangement is shown in figure 1. The wings were attached to the fuselage by a magnesium sleeve which was slipped over the after end of the rocket motor and onto which were welded plates for mounting the wings. A photograph of this mounting arrangement is shown in figure 2(a). Small vertical stabilizing fins were also attached to this sleeve.

The models were boosted to a Mach number of approximately 1.5 by a solid fuel ABL Deacon rocket motor. After separation of the model from the booster, the rocket motor of the model ignited and carried it to the top Mach number obtained in the test. A photograph of model 2 with booster on the launcher is shown in figure 2(b).

Test Wings

Three pairs of wing—ram-jet-nacelle combinations were tested in this investigation. In plan form the wings were generally similar but small vertical fins were added to the top and bottom of the nacelles for the second and third tests. Plan views of the three wings are shown in figure 3 and a side view of the vertical fins of models 2 and 3 is shown in figure 4. The fins were placed so that the fin midchord line intersected the midchord line of the wing.

The inlet of the nacelle was scaled back to A_2 (fig. 3) but no attempt was made to reproduce the flow through the duct. The ratio of the minimum area at A_2 to the cowl area at A_1 was 0.60 for model 1, 0.44 for model 2, and 0.60 for model 3. The internal flow was governed by the entrance geometry where a normal shock is thought to have formed and choked the flow. Losses through the duct were probably high due to separation and turbulence caused by internal construction.

The proper mass, mass-moment of inertia, and center-of-gravity location were obtained by the use of weights located inside the ram-jet nacelle. The supporting wings and vertical fins were constructed of spanwise laminated spruce with leading and trailing edges reinforced by strips of glass cloth. The wings were tapered and unswept and had an 8-percent-thick section which consisted of a straight bevel from the leading edge to the 25-percent-chord point, a curved section from the 25-percent-chord point to the 75-percent-chord point and a straight bevel from the 75-percent-chord point to the trailing edge. Airfoil coordinates are given in figure 3(a) for the wings and the airfoil section for the vertical fins is shown in figure 4. Structural characteristics for the ram-jet nacelles and supporting wings are listed in table I. Also listed in table I are test conditions at maximum velocity.

Instrumentation and Test Procedure

A two-channel telemeter was installed in each model and designed to give continuous indications of the wing bending and torsional oscillations by use of strain gages mounted near the root of the wing. Due to space limitations in the telemeter only one wing of each pair was equipped with strain gages but past experience has shown that if one of a pair of nearly identical wings flutters it will induce flutter in the opposite wing.

Atmospheric temperature and static pressure were obtained from a radiosonde. Ground apparatus consisted of a CW Doppler radar set and a radar tracking unit which were used to determine the model velocity and its position in space.

The models were launched at the Langley Pilotless Aircraft Research Station, Wallops Island, Va.

RESULTS AND DISCUSSION

Time histories of the flight tests showing Mach number, velocity, and atmospheric density are shown in figure 5. Model 1 showed low-amplitude bending oscillations over a Mach number range of 0.98 to 1.60. These oscillations were very near the first bending frequency of the wing and were not sustained or divergent. The torsion gage showed similar oscillations at frequencies near the natural torsional frequency. The bending and torsion oscillation showed no apparent tendency to couple. A portion of the telemeter record is shown in figure 6(a). The telemeter failed at a Mach number of 1.60 but a comparison of drag measurements obtained after booster burnout and before sustainer firing with drag measurements made after sustainer burnout indicated that both wings remained on the model throughout the flight. The model attained a maximum Mach number of 1.98. Model 2 attained a maximum Mach number of 1.89. This model also showed low-amplitude wing oscillations near the natural frequencies, almost continuously from a Mach number of 1.03 to a Mach number of 1.37 and intermittently after that up to the top Mach number of the test. These oscillations were not in evidence during the decelerating portion of the flight. Portions of the telemeter record taken at the same Mach number during acceleration and deceleration are shown in figure 6(b). The oscillations could be attributed to roughness in burning of the rocket motor or to flow instability in the inlet, commonly referred to as buzz. In the test of model 3 the sustainer rocket motor in the model ignited prematurely and caused the booster to be separated from the model. As a result the model reached a maximum Mach number of only 1.35.

There was no indication of flutter in any of the three tests. Since the wings tested were less stiff than the scaled stiffness of the prototype, it is felt that the prototype should also be free of flutter up to the maximum Mach number of the tests.

CONCLUDING REMARKS

Cold-flow free-flight flutter tests at zero lift have been made on three wing—ram-jet-nacelle combinations which were 1/9-scale models of the wing and ram-jet nacelle proposed for the Grumman XSSM-N-6a (Rigel) missile. No flutter was experienced up to the maximum Mach number of the tests, $M = 1.95$ for models 1 and 2 and 1.35 for model 3. Since the mass, mass moment of inertia, center of gravity, and exterior geometry of the ram-jet nacelle were scaled and the supporting wing was scaled in plan form but made less stiff than the scaled stiffness of the prototype, it is thought that the prototype should also be free of flutter up to the top Mach number of the model tests.

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TABLE I

STRUCTURAL CHARACTERISTICS AND FLIGHT DATA

	Model 1		Model 2		Model 3	
	Wing 1	Wing 2	Wing 1	Wing 2	Wing 1	Wing 2
M_{max}	1.98	1.98	1.89	1.89	1.35	1.35
V_{max}, fps	2138	2138	2105	2105	1498	1498
ρ_{max}, slugs/cu ft . .	0.002063	0.002063	0.001875	0.001875	0.002235	0.002235
m, $\frac{\text{lb-sec}^2}{\text{in.}}$	0.0031	0.0031	0.0053	0.0053	0.0035	0.0035
I_{cg}, in.-lb-sec^2 . .	0.136	0.136	0.075	0.075	0.042	0.042
Z, in.	1.580	1.580	0.548	0.548	0.726	0.726
$a + x_{\alpha}$	0	0	0	0	0	0
a	0	0	0	0	0	0
JG, lb-in.	--------	117,200	110,600	135,600	--------	100,200
EI, lb-in.	--------	68,100	70,900	76,500	--------	65,250
f_h, cps	111.5	108	76	77	108.5	108.5
f_{α}, cps	69.5	67.5	99.5	108	139	144
d, in.	7.717	7.717	7.717	7.717	4.941	4.941

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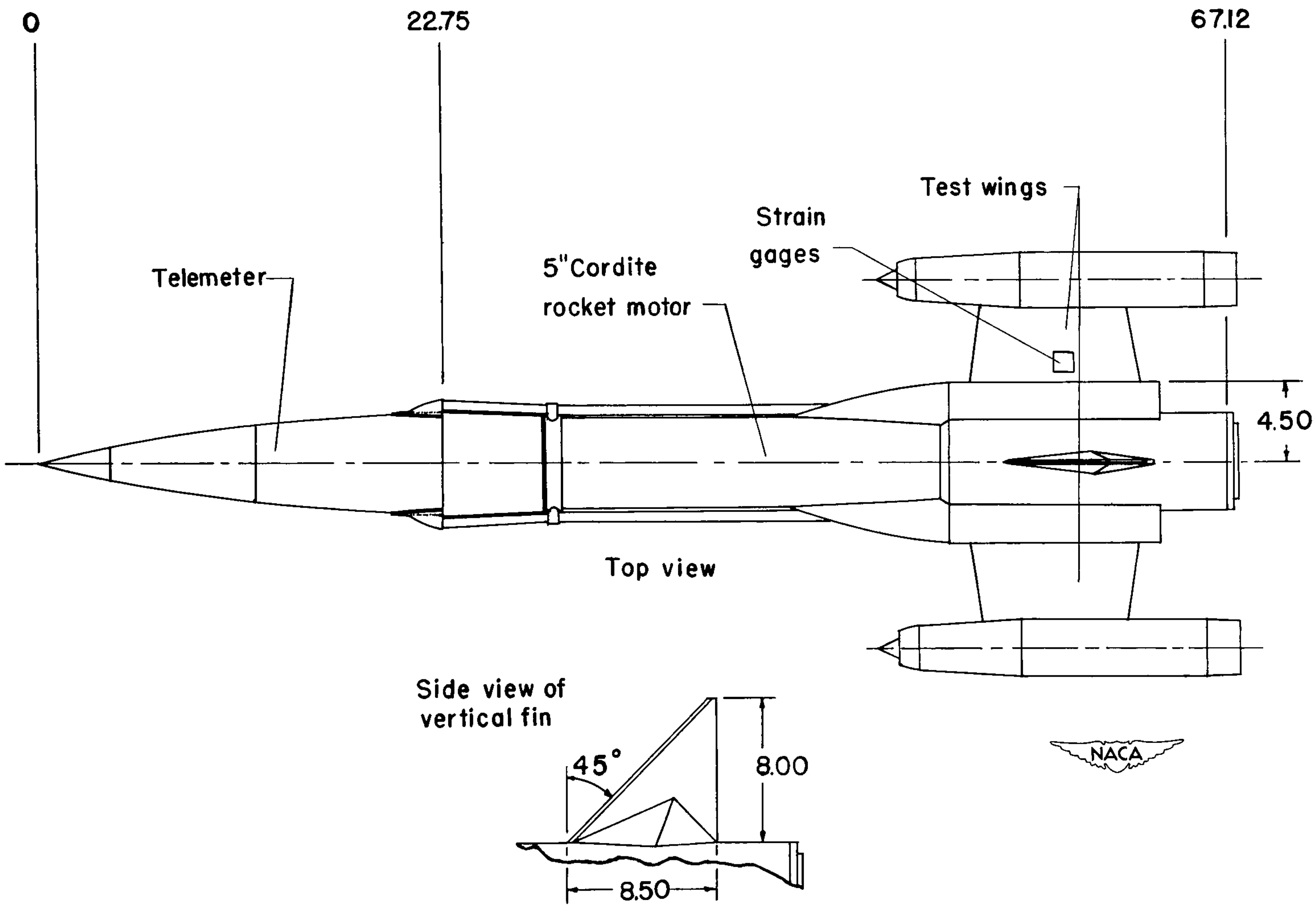

Figure 1.- General model arrangement. (All dimensions are in inches.)

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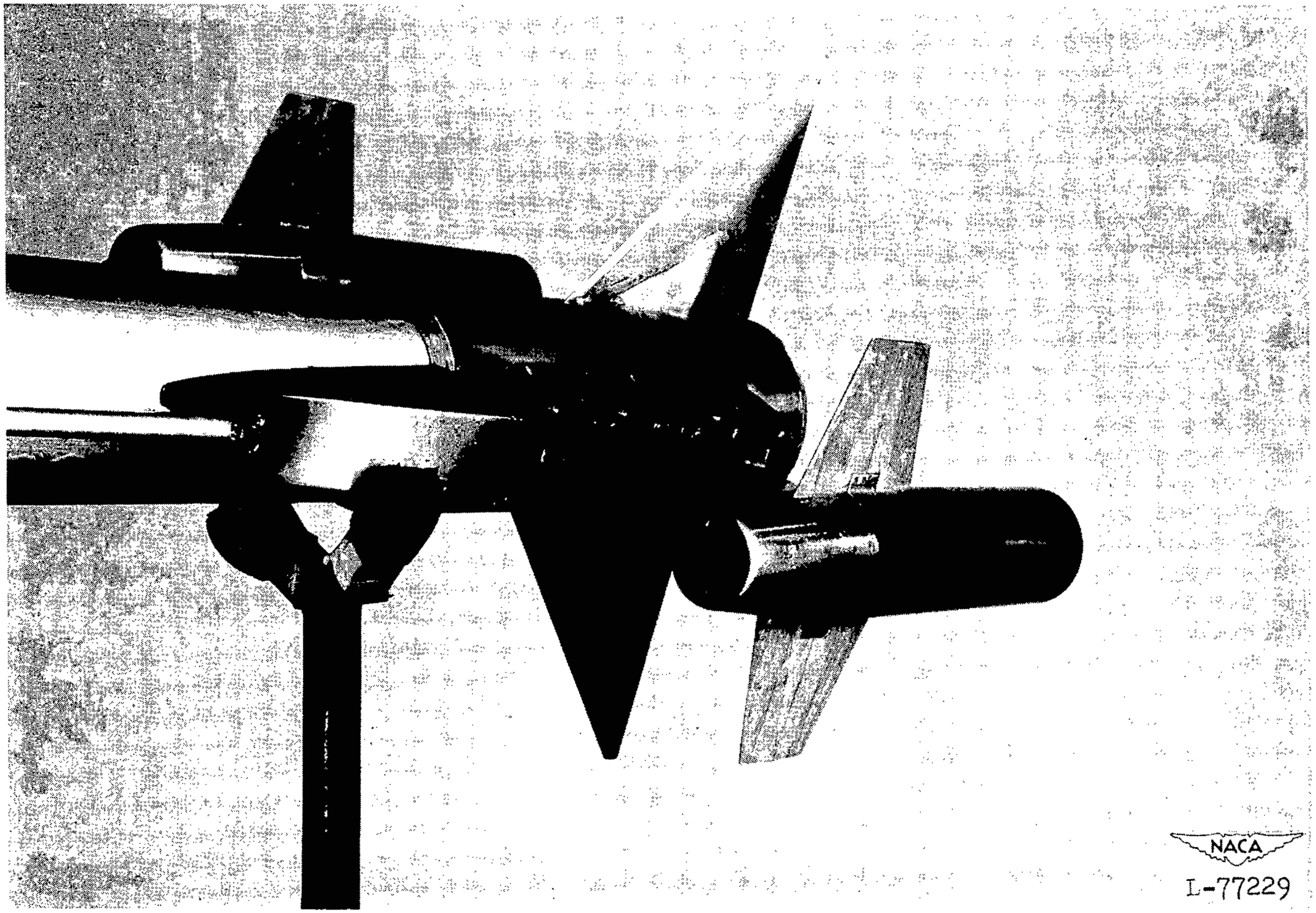
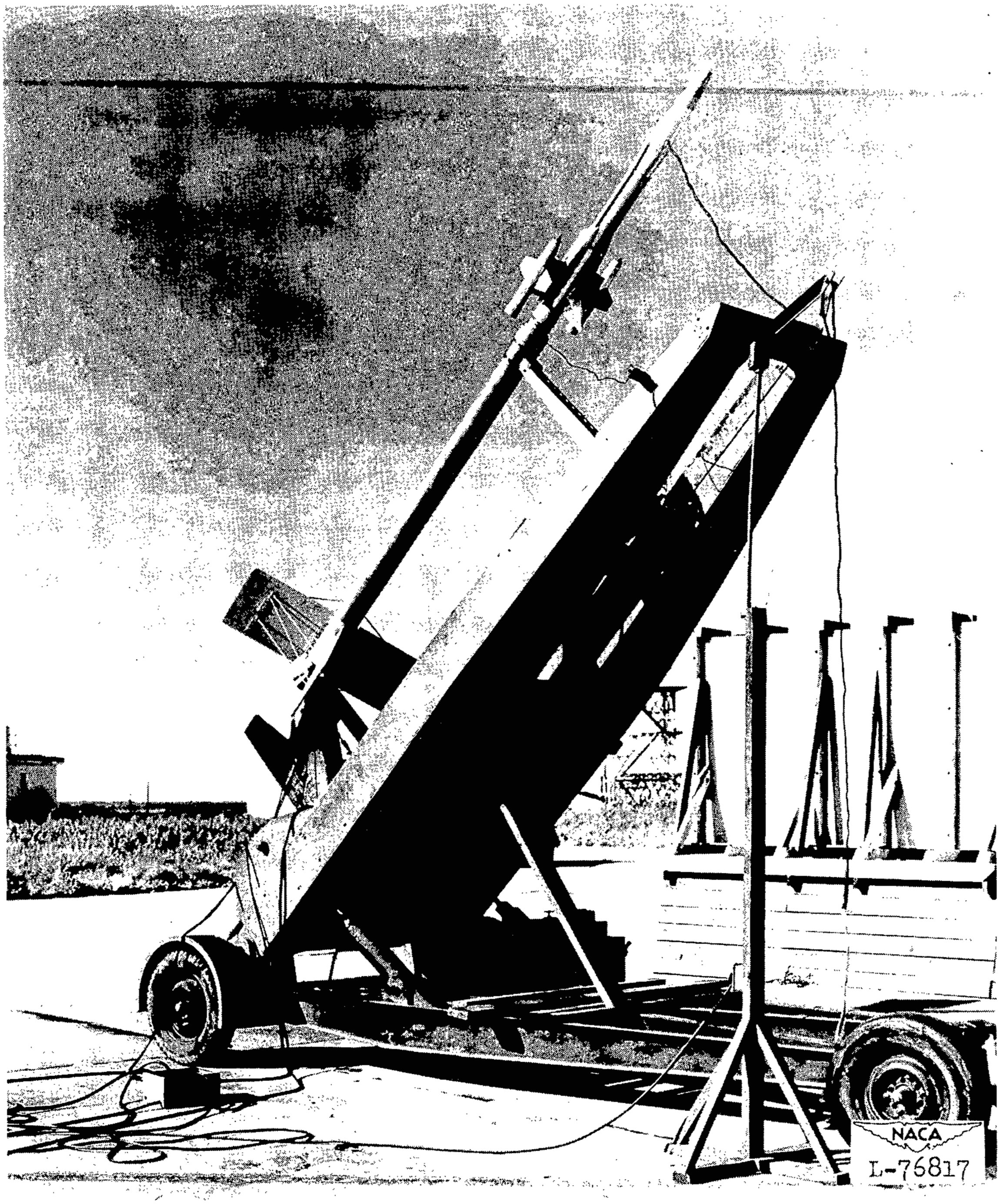


(a) After portion of model 3.

Figure 2.- Photographs of models.



(b) Model 2 with booster on launcher.

Figure 2.- Concluded.

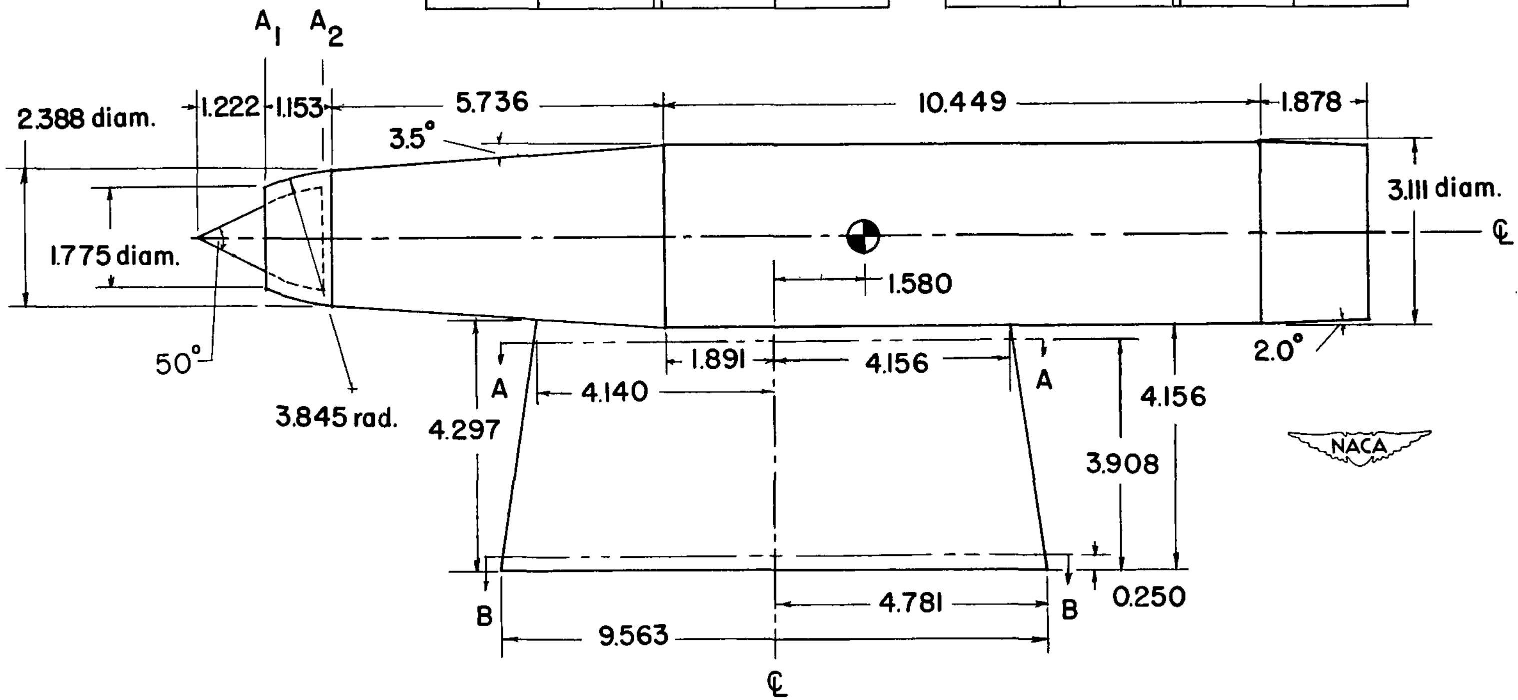
Airfoil coordinates

Section A-A

X	Y	X	Y
0	0.016	4.616	0.331
2.098	.224	5.036	.318
2.518	.264	5.455	.295
2.937	.295	5.874	.264
3.356	.318	6.294	.224
3.776	.331	8.392	.016
4.196	.335		

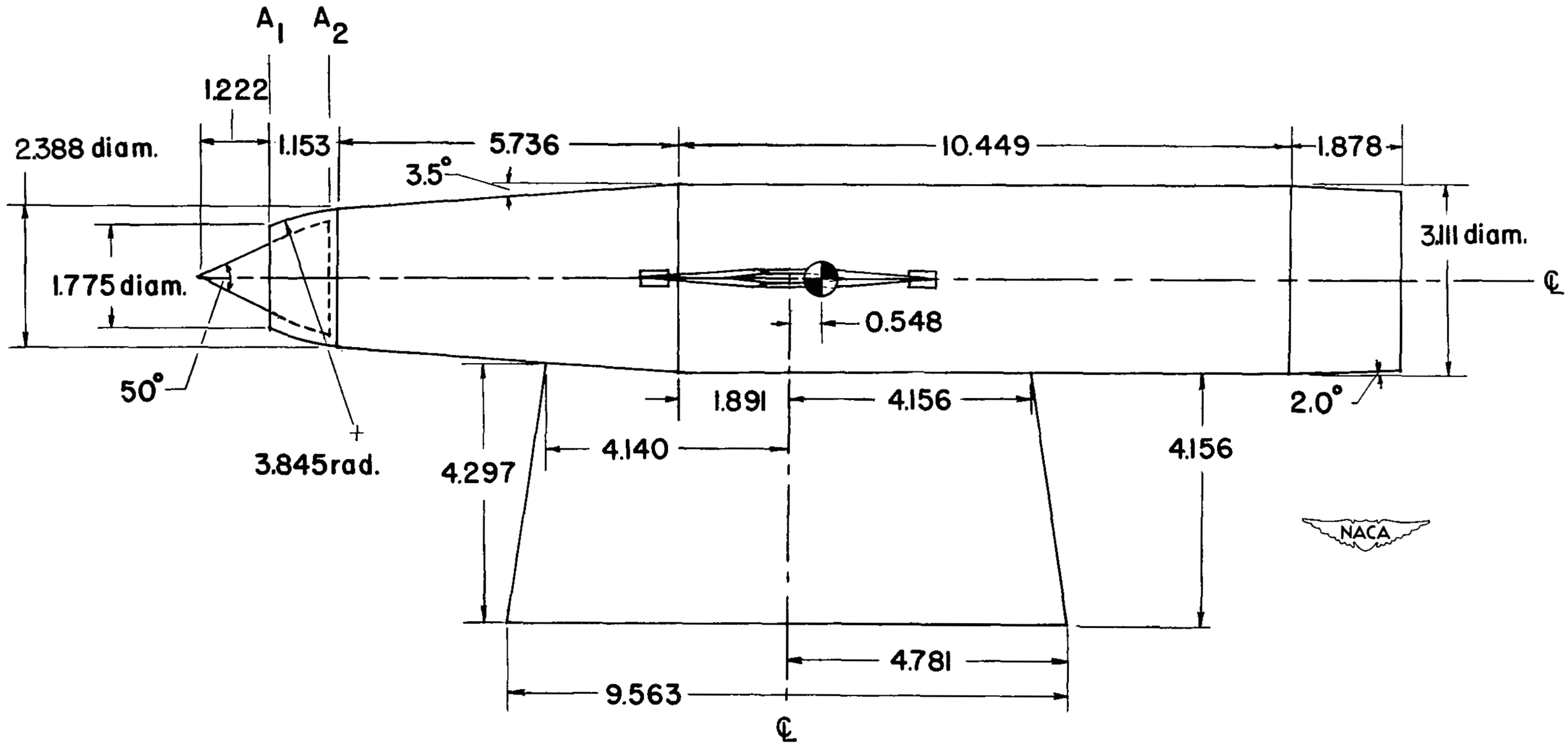
Section B-B

X	Y	X	Y
0	0.016	5.219	0.375
2.372	.253	5.693	.360
2.848	.299	6.167	.334
3.323	.334	6.642	.299
3.797	.360	7.118	.253
4.271	.375	9.490	.016
4.745	.380		



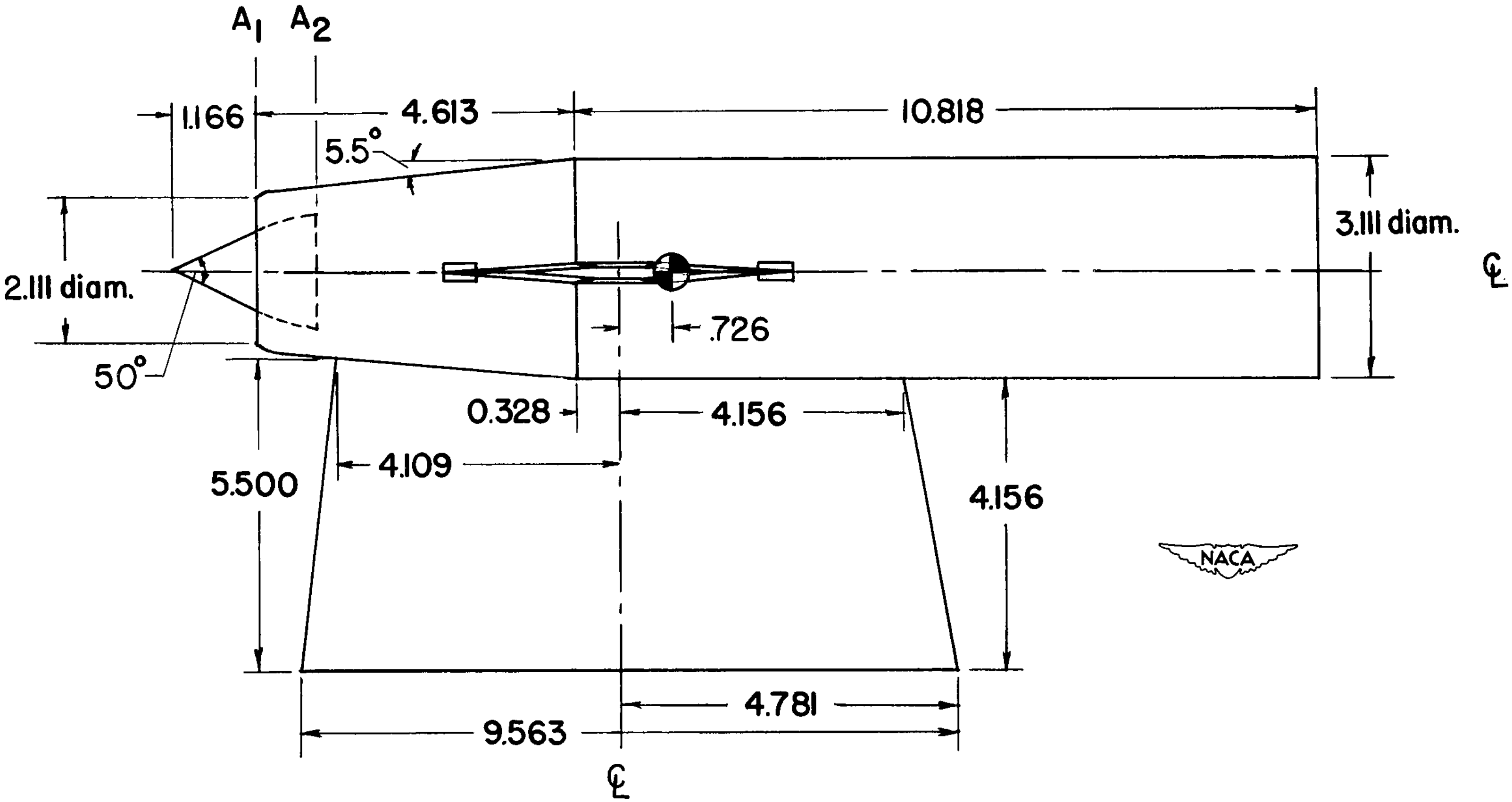
(a) Model 1. (All dimensions are in inches.)

Figure 3.- Layout of wing-nacelle.



(b) Model 2. (All dimensions are in inches.)

Figure 3.- Continued.



(c) Model 3. (All dimensions are in inches.)

Figure 3.- Concluded.

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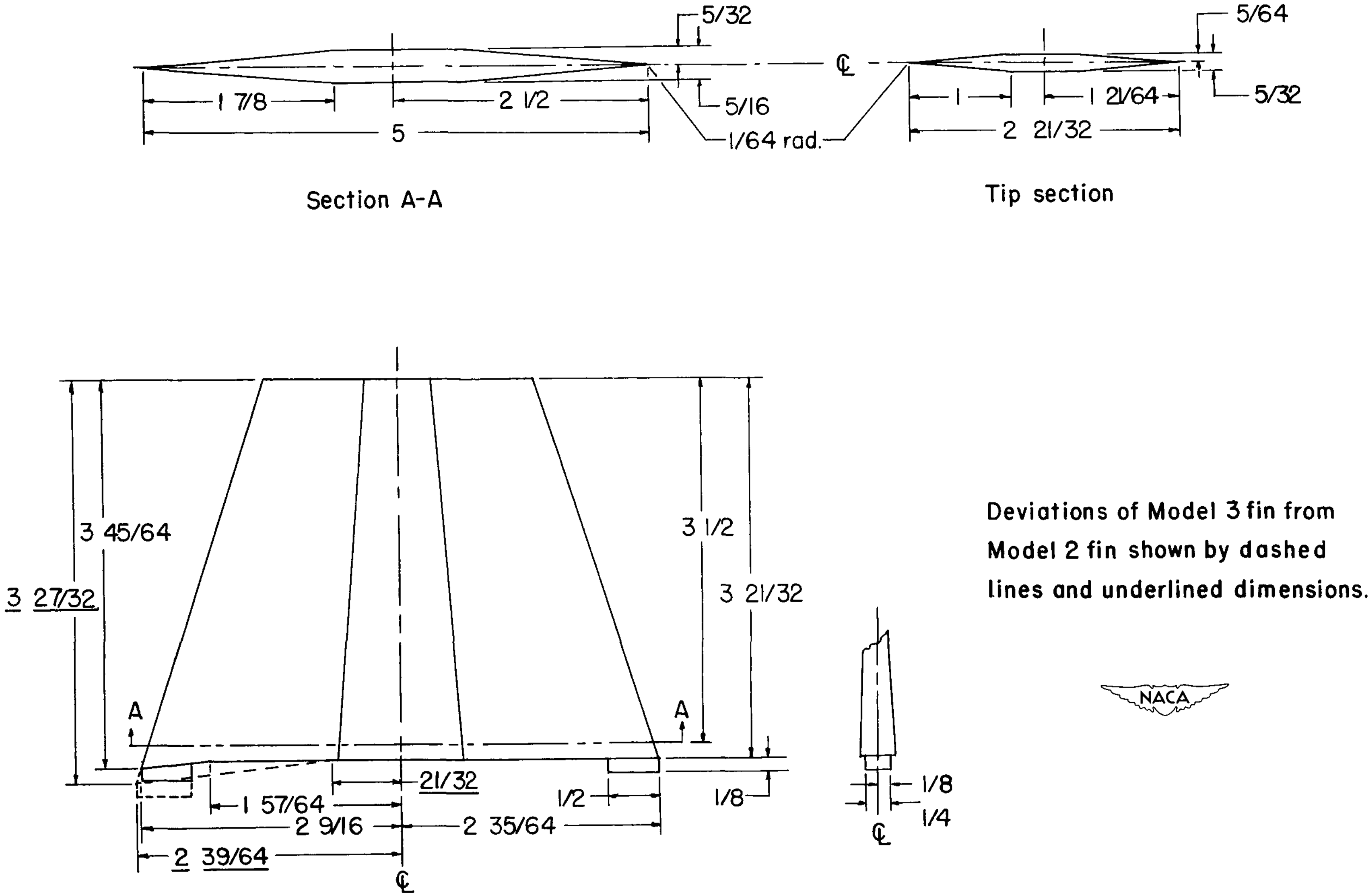

Figure 4.- Vertical fins used on models 2 and 3. Midchord lines of fins intersect midchord lines of wings. (All dimensions are in inches.)

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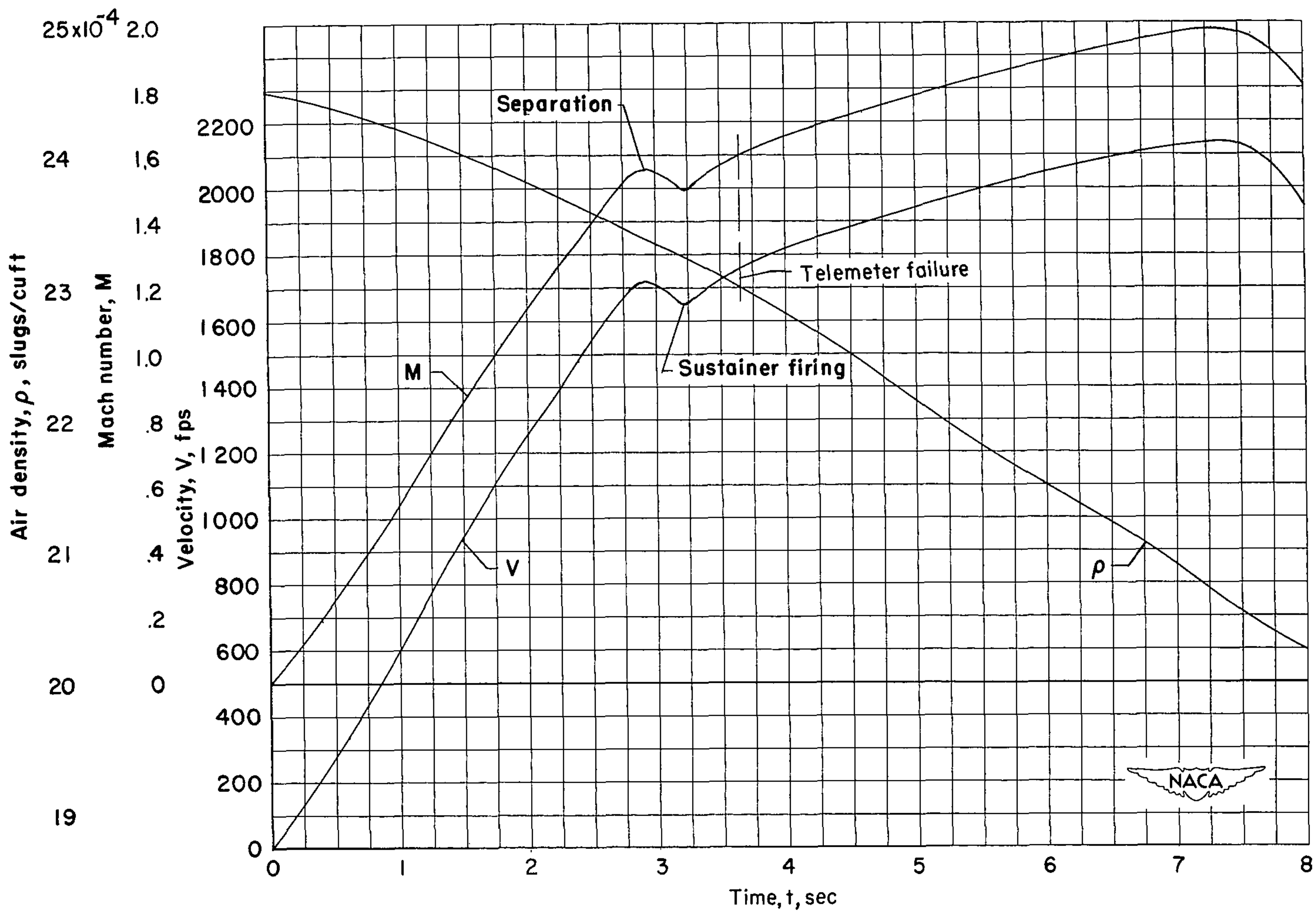

(a) Model 1.

Figure 5.- Time history showing velocity, Mach number, and air density.

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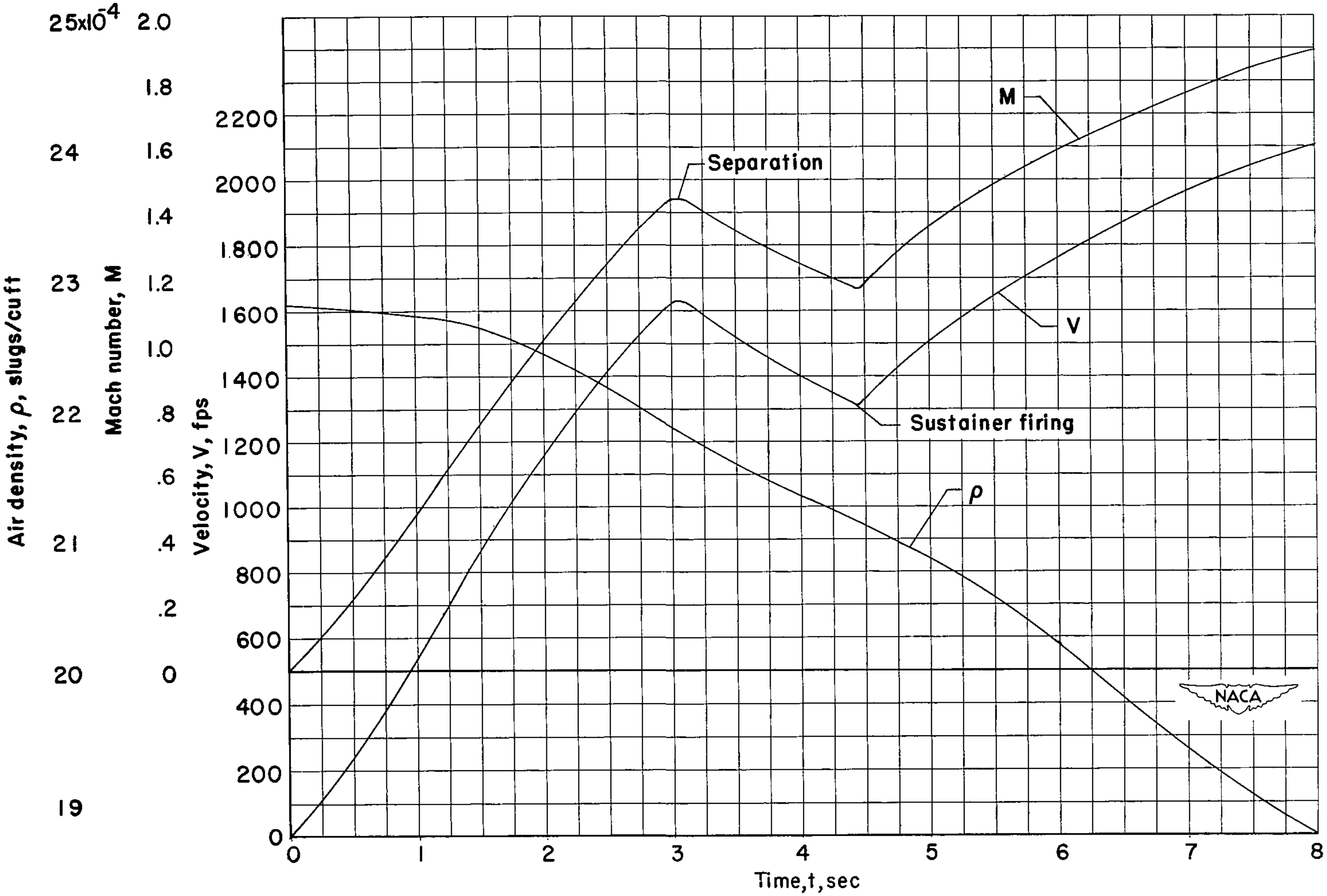

(b) Model 2.

Figure 5.- Continued.

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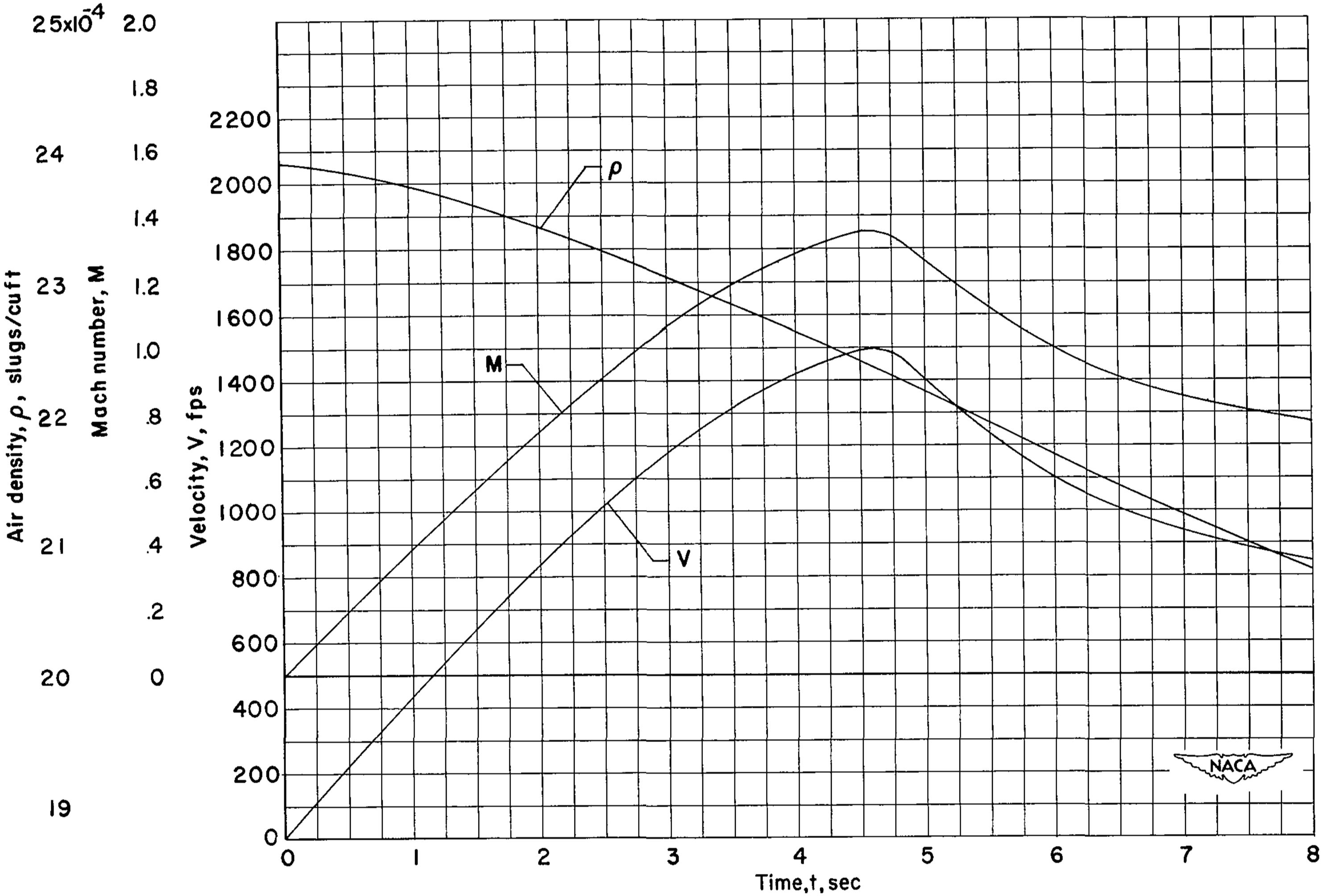

(c) Model 3.

Figure 5.- Concluded.

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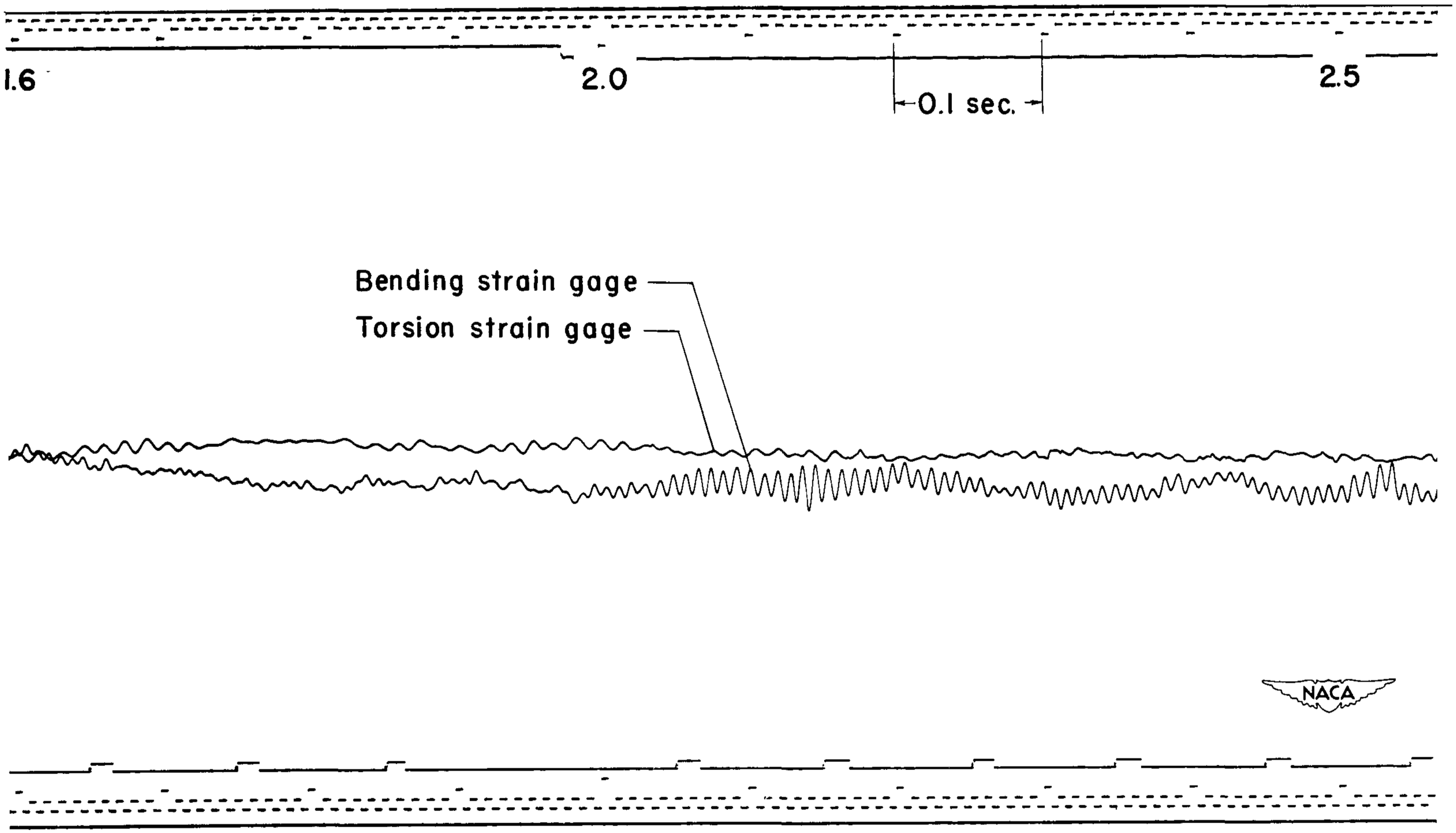

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(a) Model 1.

Figure 6.- Portions of telemeter records.

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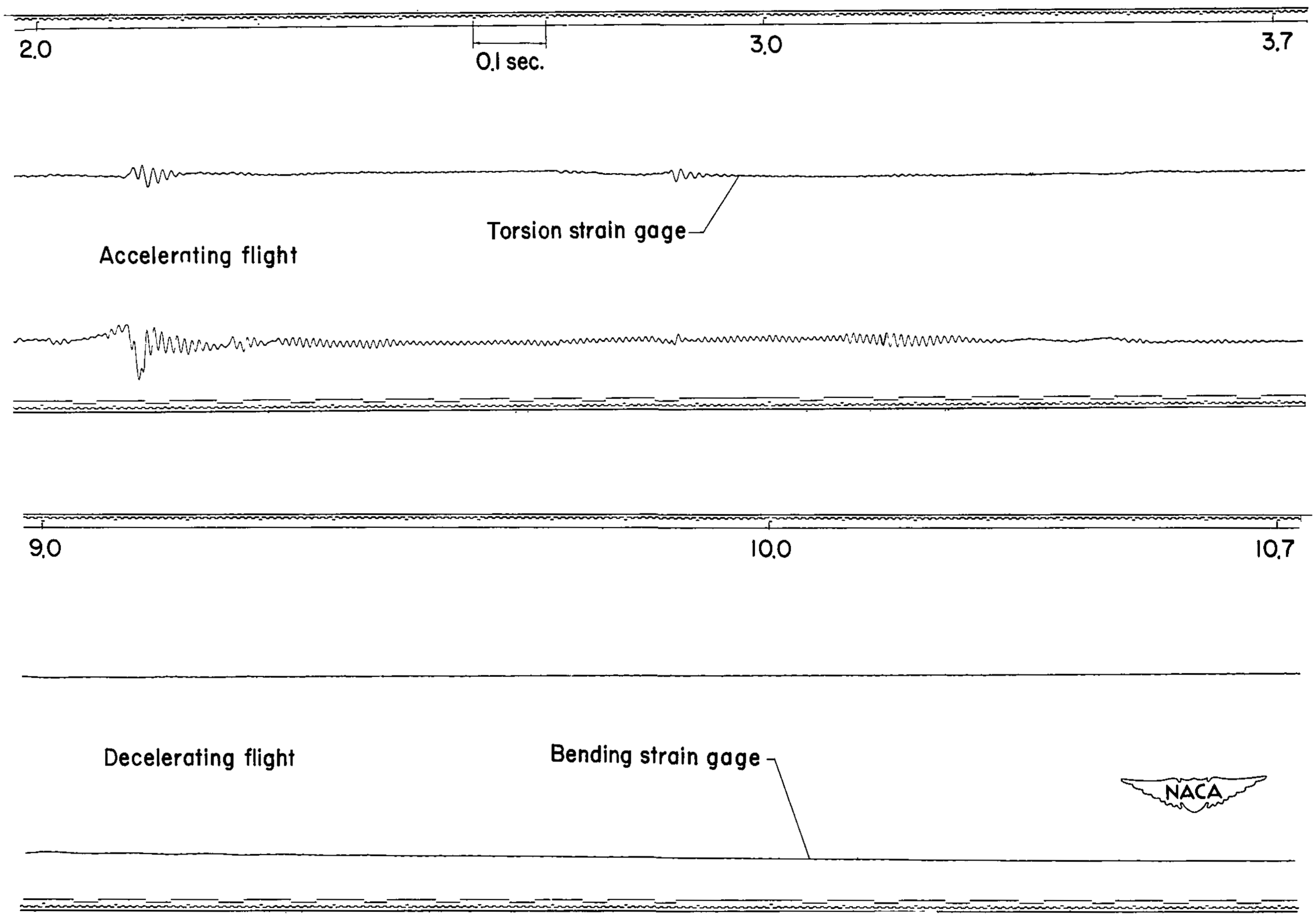

(b) Model 2.

Figure 6.- Concluded.

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